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ABSTRACT

Based on observation, interviews, and questionnaires, the first section of this paper discusses lessons learned while watching teachers use the first set of "The Voyage of the Mimi" materials (a video, computer, and print package). The focus is on the need to create an environment that will support an inquiry-based curriculum. The second section describes the design of one of the software modules, Maya Math, to address this need. A segment of the module is explained, and ways in which the materials have been designed to facilitate the discovery of specific math concepts are illustrated. Experiences of a teacher currently field testing the module are then presented. (7 references) (MES)

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INTRODUCTION

In *The Process of Education*, Jerome Bruner asked: "How can we construct curricula that can be taught by ordinary teachers to ordinary students and that at the same time reflect clearly the basic or underlying principles of various fields of inquiry?" Twenty-five years later, software designers and researchers are faced with the same dilemma. The discovery method is still perceived by many elementary school teachers as an innovation. So too are multimedia curricula that include such technologies as television and computer software. In *The Voyage of the Mimi*, technology and inquiry are combined to provide unique opportunities for elementary and middle-school students and teachers to explore topics in science and mathematics.

Mimi materials were first made available to schools in 1985; a second set is scheduled to be introduced in the fall of 1988. The centerpiece of the package is the 13-part television show that portrays the adventures of a group of young scientists. The theme of the first "season" is the study of whales in the North Atlantic; in the upcoming season, the focus will be Maya archaeology in the Yucatan Peninsula of Mexico. In both seasons, the dramatic episodes are accompanied by documentaries and computer modules, both of which develop scientific themes from the show. *Mimi* software models a variety of adult uses of technology: a training simulation, a microworld, a programming environment, and a microcomputer-based physics lab. Also included in the *Mimi* package are books with text versions of the video material, classroom activities, and additional factual information, as well as student guides for the computer modules.

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[1]Paper presented at the American Educational Research Association, April 1987.

[2]Parts of this report are based on work carried out by the research staff of the Bank Street College Mathematics, Science and Technology Teacher Education Project, which is funded by the National Science Foundation, Contract #TE1-8319705. MASTTE researchers: Laura M. W. Martin (Director of Research), Mary McGinnis, and Maxine Shirley. MASTTE training staff: Regan McCarthy (Project Director), Susan Friel (Director of Training), Marilyn Quinsaat, Tom Roberts, Bill Roberts, and Stanley Chu.

[3]*The Voyage of the Mimi* was funded by the U.S. Department of Education, Contract #300-81-0375, with additional funding by CBS, Inc. *The Second Voyage of the Mimi* was funded jointly by the U.S. Department of Education and the National Science Foundation, with funding administered by the D.O.E. under Grant #G008510039. *The Voyage of the Mimi* is published by Holt, Rinehart and Winston. Staff for *The Second Voyage of the Mimi* software development: Samuel Y. Gibbon, Jr. (Executive Producer), Lorin A. Driggs (Director of Administration), Shari Robinson (Curriculum Coordinator), Ralph Smallberg (Product Manager), and Margaret Honey (Research Associate).

The authors of this paper represent three aspects of the *Mimi* project. As a member of the Center for Children and Technology (CCT) and the Mathematics, Science and Technology Teacher Education (MASTTE) project, Laura Martin observes teachers who have been trained to use the materials from the first season. Shari Robinson, a member of the *Mimi* staff, coordinates the design of the second season software. Margaret Honey, a research associate at CCT and a *Mimi* staff member, conducts formative evaluations of the new software and documentaries. In this paper, we will describe some of the lessons we have learned watching teachers use the first season *Voyage of the Mimi* materials, and the ways in which we are applying that information to the design of one of the learning modules that will accompany *The Second Voyage of the Mimi*.

FIRST SEASON RESEARCH

Under the auspices of the MASTTE project, 82 teachers and staff developers from 13 districts across the country were introduced to the first *Voyage of the Mimi* materials and to principles of inquiry-based instruction. The one-week training sessions included workshops, lectures, discussions, and demonstrations. Over a period of two years, we observed the teachers using the materials in their classrooms; we also interviewed them and asked them to fill out questionnaires. These data pointed to important features of each technology--video, computer, and print--that affected their incorporation into teaching routines and instructional settings. Each medium created unique opportunities for innovation; nevertheless, the existing classroom culture exerted a strong influence on the way the materials were used (Martin, 1987).

Initially, everyone--from novice science teacher to veteran--felt that there were exciting ideas in the package and that the program was pertinent to the curriculum. Some teachers used the materials as a complete science and math program, while others used them to supplement existing curricula. The content of the materials intrigued the students, all of whom begged for more science time. Lessons based on the video narrative, the self-guided computer software, the students' own questions about whales and related science content added up to heightened student involvement and lively classroom interactions.

There were many positive outcomes resulting from the variety and richness of the materials in addition to the passionate level of teacher and student involvement in the project. First, there was a powerful link between the student text and the video narrative, as children regularly asked to take the *Mimi* books home. They also checked out related science and nature shows at home, and sought out books on subjects related to these shows. Second, students often asked to use the software in their free time. This translated into a benefit for teachers who were uncomfortable initially with the computer portion of the classroom modules. They found they could stand back and watch as the students played the games and join in at their own pace.

Although the program was embraced by the wide range of teachers we studied, few of them were able to adopt or sustain a style of teaching that encouraged discovery learning. It was often the case that the teachers would maintain control of classroom discussions, ask the majority of the questions, and reward students for guessing correctly. These answers ranged from discrete pieces of information (e.g., "What kind of whales were the scientists studying?") to more complex concepts (e.g., "What is a good strategy for finding your location at sea?"). Only those teachers with experience in inquiry-based instruction used the materials in open-

ended ways; the others needed ongoing help to maintain a classroom climate that emphasized reasoning rather than right answers.

Here is an example of a questioning strategy that contrasts with the ones listed above. A teacher showed an episode in which the crew of the Mimi confronted a number of problems, from equipment failure to getting lost. He asked the children what solution strategies they noticed the characters using. At the same time, the teacher encouraged the children to generate alternative solutions to the problems and to recount related incidents from their own lives. The teacher created a matrix on the board into which he entered students' responses so that patterns of strategies emerged (see Figure 1).

Judging by the process the students went through, it would have been ineffective for the teacher merely to have listed the problems from the show and conducted a recall lesson in which students matched solutions to problems. Instead, the teacher performed the critical function of tying the children's experiences to those of the scientists', allowing them to derive their own meaning from the episode.

Although the materials and training did not guarantee that teachers organized inquiry learning experiences for children, each successful class period gave teachers the courage to try more new activities and techniques. As they did so, they found themselves doing their own discovery learning. One veteran teacher made a few mistakes while demonstrating the computer navigation game to his class. He remarked to the researchers that, for perhaps the first time, he realized he did not have to know everything. In fact, by learning with his students, he could model problem-solving strategies for his class.

In summary, we learned from the first-season *Mimi* research that teachers need support as they adopt materials that are innovative in content and form. What can happen--in spite of genuinely good intentions--is that teachers will superimpose an expository teaching style on what was designed to be an inquiry-based curriculum. Instead of creating an atmosphere in which ambiguity is tolerated and student questions are encouraged, teachers tend to maintain their traditional role of information dispenser by reorienting activities and discussions toward convergent goals such as factual recall of details.

We saw a developmental process, however, in which the media and materials allowed teachers to teach in new ways and to learn new aspects of their students' learning capabilities. It was clear that with support this process could be accelerated to produce the kind of lessons that promote true thinking skills.

We have attempted to take the lessons learned from the first season and incorporate them into the design of the second season materials. In particular, we have tried to build into the classroom modules an explicit structure that will facilitate the practice of discovery-based learning. In the second half of this paper, we will describe the design of one of the software modules, Maya Math, and discuss the specific ways in which we have attempted to create an environment that will support change in classroom practices.

SECOND SEASON DESIGN

The domain of mathematics presents an interesting challenge to curriculum designers whose primary goal is to support inquiry-based learning methods. Perhaps more than any other subject area, elementary school mathematics encourages a kind of learning that is antithetical to the principles of discovery. Arithmetic, in par-

PROBLEM	SOLUTION
Knowing where to go	Map reading, compass reading: navigation
Storm	Emergency procedures
Getting back	Navigation
Seasickness	Medical equipment, walking around, going on deck to vomit
Electrical	Knowing about electricity, tools, wires, and fuses
Boat sinking	Lifeboats
Instruments don't work	Fix power supply, use other equipment that works without electricity

Figure 1. Blackboard Matrix

ticular, places a premium on acquiring the correct algorithm to master a particular skill (e.g., addition, subtraction) and to get the right answer.

More often than not, arithmetic operations involve the use of computational or technical knowledge that encourages students to apply a set of procedural rules to solve a particular problem (Lampert, 1987). Procedural knowledge is certainly useful, perhaps essential, to the doing of mathematics. However, recent research in the field of mathematical cognition suggests that a student who is able to draw on several domains of mathematical knowledge--concrete, procedural, and conceptual --is more likely to be able to select methods "that are mathematically appropriate [to a problem] and to recognize that what he or she knows can be applied in a variety of different contexts" (Lampert, 1987, p. 6. See also Davis, 1984; Leinhardt, 1985; Nodding, 1985).

Dr. Magdalene Lampert, a math educator at Michigan State University, is the principal advisor for "Maya Math" and the author of the book that accompanies the software. Lampert has found that one of the most important factors influencing pedagogic style is how teachers perceive a knowledge domain itself. Teachers who are able to see mathematics as a field of inquiry are more likely to use nontraditional methods that encourage students to develop and articulate strategies for solving problems and to share their ideas with one another (Lampert, 1986).

With these goals in mind, we have taken advantage of the Ancient Maya theme of *The Second Voyage of the Mimi* to present a particular aspect of mathematics as an archaeological expedition. In the classroom learning module, "Maya Math," students are asked to adopt the role of archaeologists attempting to decipher the meaning of Maya number glyphs. The print materials encourage teachers and students to use an open-ended hypothesis-building and testing approach as they try to make sense of the bars, dots, and shells found by archaeologists on the carved monuments and in the hand-painted books left behind by the Ancient Maya. In the course of their investigations, students will encounter basic mathematical concepts, such as numeration, place value, and the role of zero. Given this exploratory context, we hope teachers will feel comfortable letting go of traditional approaches to mathematics and will experiment with guided discovery techniques.

The curriculum materials include three computer software programs, one of which is a utility that enables students to explore the Maya base-20 system (and other bases as well). In what follows, we will explain a segment of the module and illustrate the ways in which the materials have been designed to facilitate the discovery of specific math concepts.

Figure 2 is a carved panel from a classic Maya site (ca. AD 795). Students examine this photograph after they have been introduced to Maya culture and archaeology in the first few episodes of *The Second Voyage of the Mimi*. The teacher asks them to look at this panel as though they were the first archaeologist to find it on the wall of a temple deep in the jungles of Mexico or Guatemala. What do they make of it? What are the marks on either side of the figure? If they represent writing, what are words and what are numbers?

Exploration of the signs and symbols in this panel can go on for a very long time. Some students will come upon the bars and dots sooner than others. The print materials suggest to teachers that they give all their students a chance to present their observations and hunches without closing in on the correct interpretation too soon. They are encouraged to attend to their students' reasoning processes and to help them listen to one another. The fact that archaeologists cannot turn to someone and

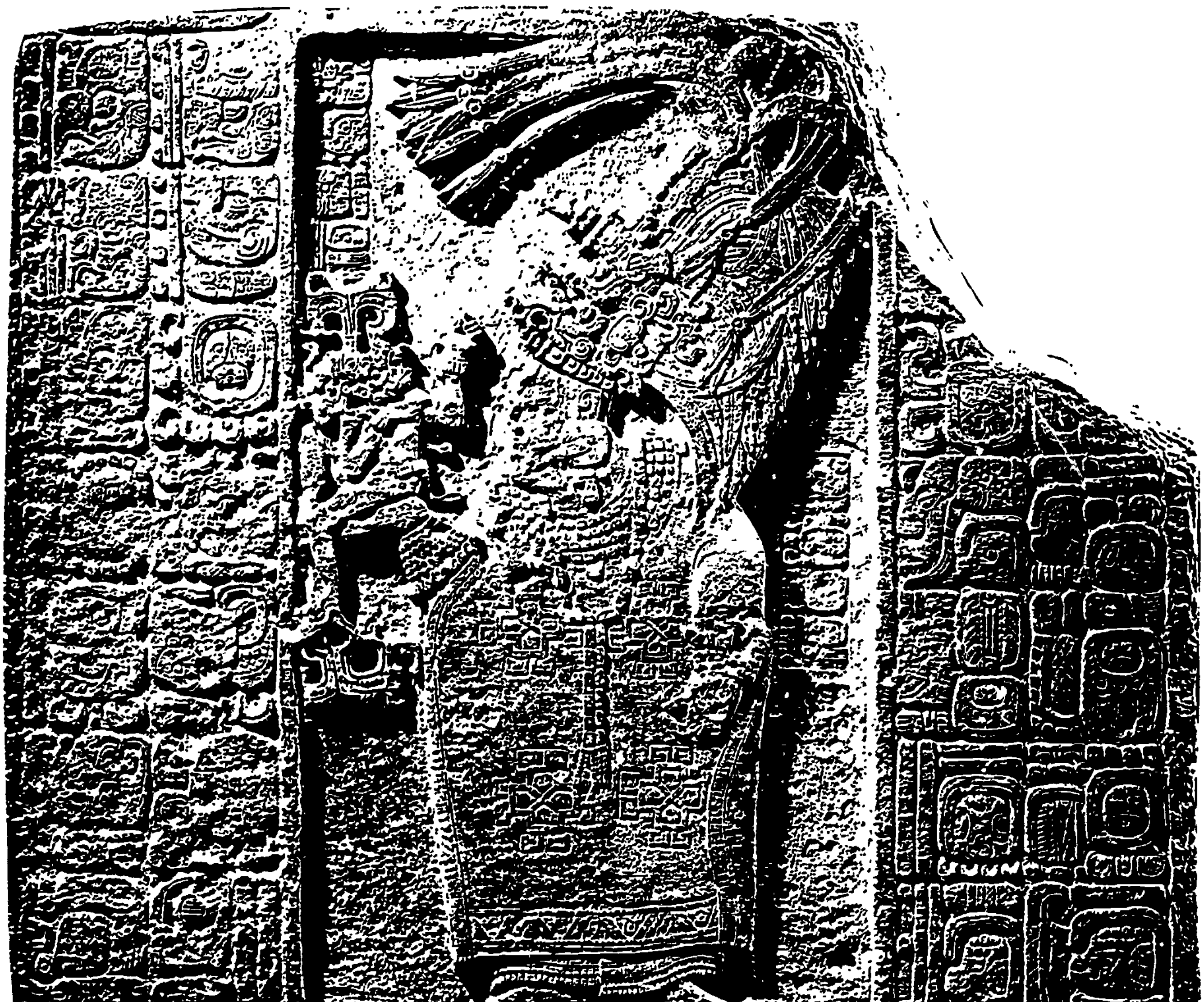

Figure 2. Carved Panel from Classic Maya Site

ask "Am I right?" provides a compelling model for teachers and students, who are usually eager to arrive at a correct answer as quickly as possible.

Once the class has agreed that the bars and dots in the picture represent numbers (the teacher and the text will confirm this hypothesis), they can look for regular patterns in the figures they see. For example, what is the maximum number of dots and bars in any one place? At this point, the text provides information about the ways in which other cultures represent numbers, leading students to make comparisons with the Maya evidence they have seen so far.

The "Maya Calculator" is a program that runs on 128K Apple II computers. Teachers can use this software for whole-group discussions, or students can "mess around" on their own. There are also open-ended challenges in the text for students to try with the software. The calculator allows users to explore the Maya number system through five places (see Figure 3).

Students quickly pick up on the fact that the Maya made a dot for 1 and a bar for 5, and that this relates to counting on one's fingers (dot) and hands (bar). They also discover that there are never more than 4 dots or 3 bars in any one place.

In the context of a teacher-guided discussion, students are asked to think about how place value works in the Maya system. The teacher uses the calculator to count to 20, and students are asked to formulate hypotheses about what the shell symbol stands for in the number 20 and how they think the Maya wrote numbers larger than 20 (see Figure 4). The teacher continues to use the calculator to count to 39, and students are asked to speculate about what the number 40 will look like. Students in the upper elementary grades are usually unable to generalize to the other places at this point. They need to continue counting to find out what happens when they "fill up" the first and second places.

At this point, students start to see the pattern of multiples of 20 emerging. The text materials build on this discovery by reviewing powers of 10 in our own number system. From there, students can return to the Maya number system and speculate on the next place (400) and the next (8,000) and the next (160,000) and any others that extend beyond the limits of the computer screen. The calculator also allows adventurous teachers and students to take a trip in time back to the Classic Period of New Math (ca. 1965) to explore other bases between 2 and 20.

In summary, this learning module uses a different number base to help students step outside of their own number system and thereby gain a more articulated understanding of place value. With this curriculum, we hope to encourage a procedure for discovery and an attitude toward mathematics that will be sustained through the module and will carry over into other areas of the math curriculum as well.

SECOND SEASON RESEARCH

We are currently field testing this classroom module. One of the people we are working with is a math teacher from a middle-class, racially diverse elementary school outside of New York City. Although her approach to teaching is traditional, she explained to us that she and the other math specialist in the school would welcome more opportunities to encourage discovery learning among their students. However, because of constraints on their time and the fact that they have never found a math curriculum for the upper grades that supports such an approach, they have not attempted to put into practice a discovery-learning program.

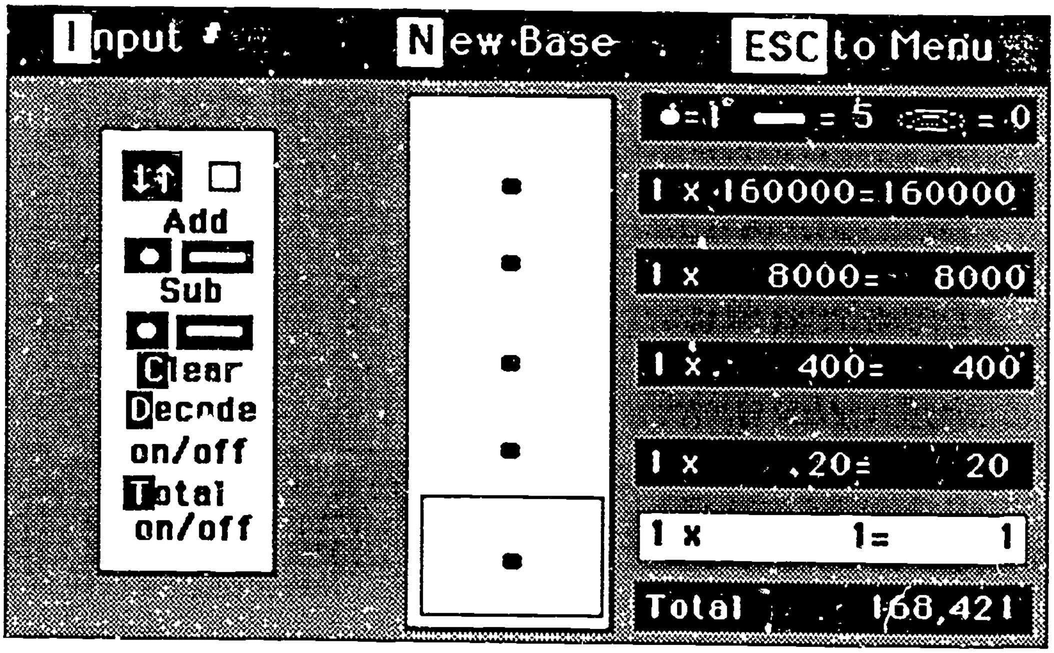

Figure 3. Maya Calculator

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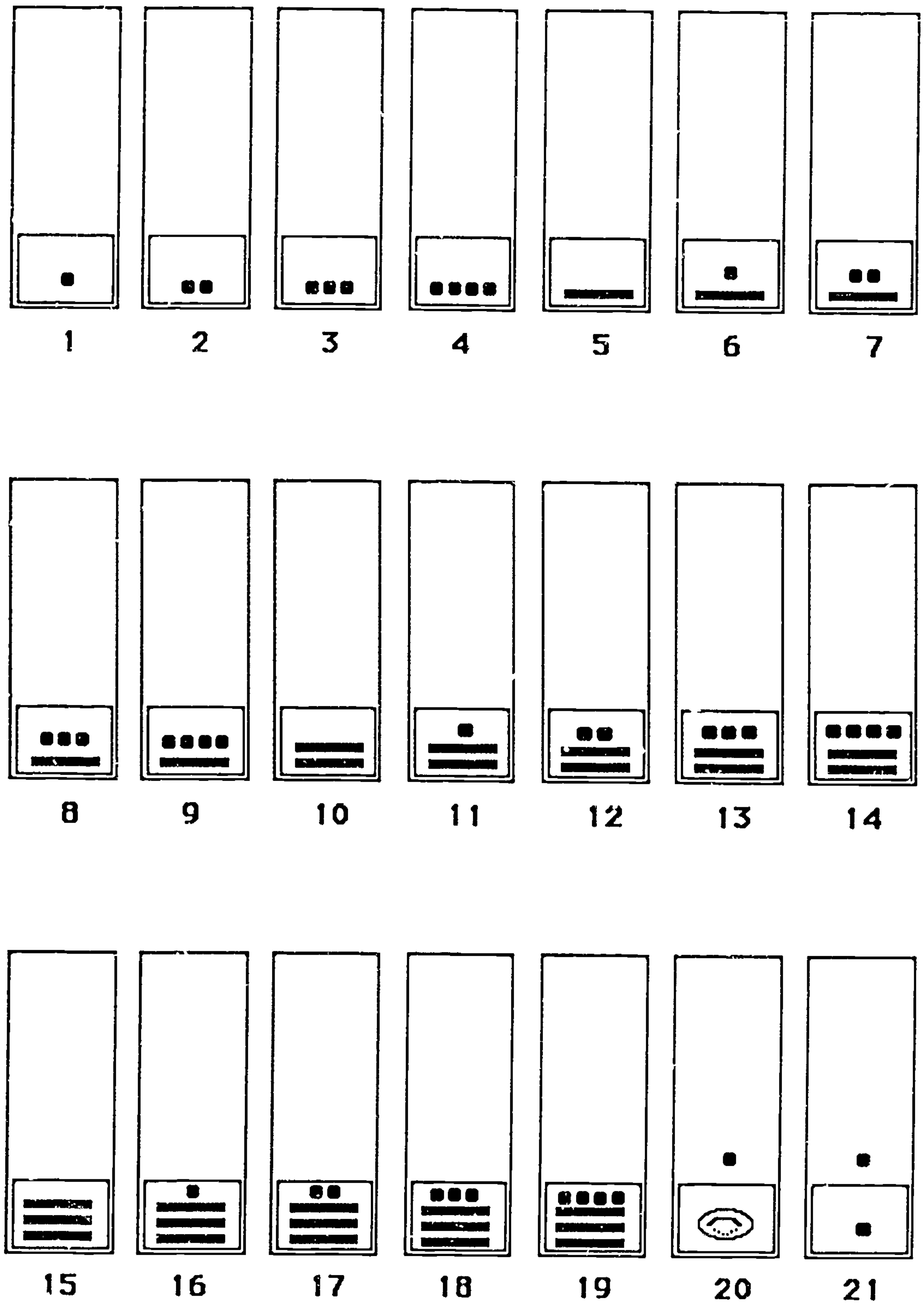

Figure 4. Counting to 21

From the beginning, this teacher has been extremely enthusiastic about using the "Maya Math" software and print materials to support a new kind of inquiry into place value. We observed the first lesson she conducted with a group of sixth graders, in which she drew on their existing knowledge about other cultures and number systems. She helped students use what they already knew as a basis for thinking about Maya math. She moderated a very exciting and open-ended discussion on "the illustration you have seen about the kinds of symbols the Maya might have used to represent numbers."

The discussion was one that could have carried over easily into another class period. However, the teacher halted the process by giving the students a handout that explicitly stated the rules of the Maya number system. In effect, she fell back on her familiar and expected role of information giver and threatened to bring premature closure to the students' explorations.

There was, however, an interesting outcome to this incident, one that paralleled the experience of the first season *Mimi* teacher who discovered he could make mistakes along with his students. At the end of the class period, she said that she realized that she should have allowed her students to engage in a more extensive evaluation of their hypotheses about Maya numbers. In that way, they could arrive themselves at the very conclusions she had so carefully laid out, with the result being far more effective learning.

This brief anecdote illustrates two things: First, even when math teachers are enthusiastic about using discovery methods, and even when these methods are explicitly supported by computer tools and text materials, it is difficult for teachers to change their conception of arithmetic as a domain of knowledge characterized by facts and procedures. Second, the concept of teacher training itself may need close examination and revision to include more examples of the very process we advocate for children--discovery learning. The most powerful lessons teachers learned using *The Voyage of the Mimi* materials were the ones they learned for themselves.

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